Synthesis and Analysis Tools with Physical Modeling: An Environment for Musical Sounds Production

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Abstract :

We first present some tools and methods for sound synthesis, based on the physical modeling, through a general representation formalism, of musical instruments and designed for the construction and the study of vibrating network-based objects. Then we present a second class of tools, based on the same principles and formalism of physical modeling, and designed for the analysis of sounds in term of vibrating phenomenon on a time/frequency domain.

1. Introduction

Within the framework of the realization of a computer environment for musical creation, we have developed a system for sound synthesis, based on the physical modeling of musical instruments. In this perspective we have been driven to study the problem of analysis and more precisely the question of the interpretation of sound phenomena in relation to the physical modeling principles used for synthesis.

This work takes place in the general purpose of the realization of an instrumental platform for musical creation.

2. Physical Modeling & CORDIS-ANIMA

The goal of any simulation is to collect some information representing a physical phenomenon. Physical modeling makes this possible by the simulation of the cause(s) of the phenomenon. If the simulation system is designed for sound synthesis, the input data are simply a static description of the structure of a physical object (presenting specific inertia and visco-elastic properties) and the modeling of a mechanical action on this object. This action (excitation), applied to the physical system gives rise to a vibrating motion. The vibration evolves by itself, according to some physical rules stated in the previous description of the cause (object and action). The output information is then collected as the time evolution of one or more physical magnitudes of the object (for example the successive positions of some of its matter points).

The CORDIS-ANIMA system developed at the ACROE [Cadoz.93] enables the computer-based modeling and simulation of physical objects that can be seen, heard and handled (with force-feedback gestural control device : the TGR). An object is a modular assembly of *elementary mechanical components* picked up amongst a limited number of types with very simple associated *elementary simulation algorithms*. Their assembly constitutes the global simulation algorithm of the modeled object. A simulation is the computation of all displacements and force transfers inside the object. This general formalism enables a great flexibility for the construction of virtual objects which may or may not have a referent in the real world.

3. Vibrating Objects for Sound Synthesis

The most important problem in physical modeling is to build the object structure and to determine the parameters of its components in order to obtain the required perceptive and interactive properties.

Thanks to this system we performed several experiments centered on the study of the basic components of an instrument. These elements of the causal chain for sound production are the vibrating structure (VS), the excitator, link element between the gesture and the VS, and below, a device (table, resonance chamber) describing the general environment.

Each of these elements, built as a network of matter points and visco-elastic links, plays a specific role that the auditory system can distinguish and identify to a large extent. The individual and combined study of these elements and what they produce, enables to determine and control some elementary musical attributes.

The review that is presented here stress more specially on the study of the Vibrating Structures, built as topological networks of particles (ponctual matter points and viscoelastic links).

This study is based on the idea of modal representation [Djoharian.93] that enables us to split up a network into a set of independent elementary oscillators and leads up to a complete knowledge of the model (mechanical and acoustic properties) [Incerti.95.b]. This representation also alows the building of very complex structures, without any reference in the real world, but designed to present specific acoustic properties.

Such a control on several levels of representation (network, physical parameters, modes) offers a wide range of possibilities for rich and realistic sound synthesis.

But the main problem that may occur in such a simulation is that, even if it is possible to get a complete knowledge of the cause, it is often very difficult to control the evolution of the phenomenon and to analyze the resulting information.

4. Analysis

In the case of a simulation system for sound synthesis it appears that beside the synthesis some control and analysis tools are needed to strengthen the knowledge of the complete process. This knowledge must first be turned to the study of the process, then to the physical object with its capabilities and its behavior when it becomes the center of the phenomenon. But this knowledge must also be turned to the results of the simulation, that is the mechanical vibrations that will be interpreted as a sound. Here appears a question: how can this sound be interpreted? As a classical digital sound signal, or as the result of a physical phenomenon with physical causes?

In order to try to give an answer, we have studied a second class of tools, based on the same principles of physical modeling, and designed for the analysis of sounds on a time/frequency domain. One of these tools enables us to describe a sound as a combination of elementary vibrating phenomena through its decomposition on a set of elementary oscillators [Incerti.95.a]. Each oscillator, acts like a digital 2d order band-pass filter and is adjusted on a given resonance frequency and a given amplitude response or bandwith.

This modal analyzer gives a physical definition of a sound in perfect accordance with the synthesis method. We have already obtained promising results with sounds of various origins (physical modeling synthesis of course, but also natural sounds) but it remains a work in progress. Some theoretical points are still to be studied with great attention and especially the links with standard signal processing techniques. We have already pointed out some limits but also some interesting properties and leads for further developments : parameters and structure identification from a sound signal, but also sound treatment process.

From a wider point of view, this approach offers a new way to consider the question of the unity of the methods in analysis and synthesis.

5. Environment for Musical Creation

Beside these technical points, these works take place in the more general context of a computer based process for musical creation. Such a system should include all the steps of production, analysis, and processing, that is from the creation of the instrument to its playing. In this perspective, we tend to develop a complete system, based on the principles of physical modeling [Cadoz.95], including the description and the construction of vibrating object and excitators, some visual interfaces for edition and control, analysis tools for objets and sounds, and the simulation system itself.

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